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                          OSPF Version 2

Status of this Memo

This RFC specifies an IAB standards track protocol for the Internet
community, and requests discussion and suggestions for improvements.
Please refer to the current edition of the ``IAB Official Protocol
Standards'' for the standardization state and status of this protocol.
Distribution of this memo is unlimited.

Abstract

This memo documents version 2 of the OSPF protocol. OSPF is a link-
state based routing protocol. It is designed to be run internal to a
single Autonomous System. Each OSPF router maintains an identical
database describing the Autonomous System's topology. From this
database, a routing table is calculated by constructing a shortest-path
tree.

OSPF recalculates routes quickly in the face of topological changes,
utilizing a minimum of routing protocol traffic. OSPF provides support
for equal-cost multipath. Separate routes can be calculated for each IP
type of service. An area routing capability is provided, enabling an
additional level of routing protection and a reduction in routing
protocol traffic. In addition, all OSPF routing protocol exchanges are
authenticated.

Version 1 of the OSPF protocol was documented in RFC 1131. The
differences between the two versions are explained in Appendix F.

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1. Introduction

This document is a specification of the Open Shortest Path First (OSPF)
internet routing protocol. OSPF is classified as an Internal Gateway
Protocol (IGP). This means that it distributes routing information
between routers belonging to a single Autonomous System. The OSPF
protocol is based on SPF or link-state technology. This is a departure

[Moy]   [Page 1]
□
RFC 1247   OSPF Version 2   July 1991

from the Bellman-Ford base used by traditional internet routing
protocols.

The OSPF protocol was developed by the OSPF working group of the
Internet Engineering Task Force. It has been designed expressly for the
internet environment, including explicit support for IP subnetting,
TOS-based routing and the tagging of externally-derived routing
information. OSPF also provides for the authentication of routing
updates, and utilizes IP multicast when sending/receiving the updates.
In addition, much work has been done to produce a protocol that responds
quickly to topology changes, yet involves small amounts of routing
protocol traffic.

The author would like to thank Rob Coltun, Milo Medin, Mike Petry and
the rest of the OSPF working group for the ideas and support they have
given to this project.

1.1 Protocol overview

OSPF routes IP packets based solely on the destination IP address and IP
Type of Service found in the IP packet header. IP packets are routed
"as is" -- they are not encapsulated in any further protocol headers as
they transit the Autonomous System. OSPF is a dynamic routing protocol.
It quickly detects topological changes in the AS (such as router
interface failures) and calculates new loop-free routes after a period
of convergence. This period of convergence is short and involves a
minimum of routing traffic.

In an SPF-based routing protocol, each router maintains a database
describing the Autonomous System's topology. Each participating router
has an identical database. Each individual piece of this database is a
particular router's local state (e.g., the router's usable interfaces
and reachable neighbors). The router distributes its local state
throughout the Autonomous System by flooding.

All routers run the exact same algorithm, in parallel. From the
topological database, each router constructs a tree of shortest paths
with itself as root. This shortest-path tree gives the route to each
destination in the Autonomous System. Externally derived routing
information appears on the tree as leaves.

OSPF calculates separate routes for each Type of Service (TOS). When
several equal-cost routes to a destination exist, traffic is distributed
equally among them. The cost of a route is described by a single
dimensionless metric.

OSPF allows sets of networks to be grouped together. Such a grouping is

called an area. The topology of an area is hidden from the rest of the
Autonomous System. This information hiding enables a significant
reduction in routing traffic. Also, routing within the area is
determined only by the area's own topology, lending the area protection
from bad routing data. An area is a generalization of an IP subnetted
network.

OSPF enables the flexible configuration of IP subnets. Each route
distributed by OSPF has a destination and mask. Two different subnets
of the same IP network number may have different sizes (i.e., different
masks). This is commonly referred to as variable length subnets. A
packet is routed to the best (i.e., longest or most specific) match.
Host routes are considered to be subnets whose masks are "all ones"
(0xffffffff).

All OSPF protocol exchanges are authenticated. This means that only
trusted routers can participate in the Autonomous System's routing. A
variety of authentication schemes can be used; a single authentication
scheme is configured for each area. This enables some areas to use much
stricter authentication than others.

Externally derived routing data (e.g., routes learned from the Exterior
Gateway Protocol (EGP)) is passed transparently throughout the
Autonomous System. This externally derived data is kept separate from
the OSPF protocol's link state data. Each external route can also be
tagged by the advertising router, enabling the passing of additional
information between routers on the boundaries of the Autonomous System.

1.2 Definitions of commonly used terms

Here is a collection of definitions for terms that have a specific
meaning to the protocol and that are used throughout the text. The
reader unfamiliar with the Internet Protocol Suite is referred to [RS-
85-153] for an introduction to IP.

Router
     A level three Internet Protocol packet switch. Formerly called a
     gateway in much of the IP literature.

Autonomous System
     A group of routers exchanging routing information via a common
     routing protocol. Abbreviated as AS.

Internal Gateway Protocol
     The routing protocol spoken by the routers belonging to an
     Autonomous system. Abbreviated as IGP. Each Autonomous System has

[Moy]   [Page 3]

RFC 1247   OSPF Version 2   July 1991

     a single IGP. Different Autonomous Systems may be running different
     IGPs.

Router ID
     A 32-bit number assigned to each router running the OSPF protocol.
     This number uniquely identifies the router within an Autonomous
     System.

Network
     In this paper, an IP network or subnet. It is possible for one

physical network to be assigned multiple IP network/subnet numbers.
We consider these to be separate networks. Point-to-point physical
networks are an exception - they are considered a single network no
matter how many (if any at all) IP network/subnet numbers are
assigned to them.

Network mask
    A 32-bit number indicating the range of IP addresses residing on a
    single IP network/subnet. This specification displays network masks
    as hexadecimal numbers. For example, the network mask for a class C
    IP network is displayed as 0xffffff00. Such a mask is often
    displayed elsewhere in the literature as 255.255.255.0.

Multi-access networks
    Those physical networks that support the attachment of multiple
    (more than two) routers. Each pair of routers on such a network is
    assumed to be able to communicate directly (e.g., multi-drop
    networks are excluded).

Interface
    The connection between a router and one of its attached networks.
    An interface has state information associated with it, which is
    obtained from the underlying lower level protocols and the routing
    protocol itself. An interface to a network has associated with it a
    single IP address and mask (unless the network is an unnumbered
    point-to-point network). An interface is sometimes also referred to
    as a link.

Neighboring routers
    Two routers that have interfaces to a common network. On multi-
    access networks, neighbors are dynamically discovered by OSPF's
    Hello Protocol.

Adjacency
    A relationship formed between selected neighboring routers for the
    purpose of exchanging routing information. Not every pair of
    neighboring routers become adjacent.

[Moy]   [Page 4]
□
RFC 1247   OSPF Version 2   July 1991

Link state advertisement
    Describes to the local state of a router or network. This includes
    the state of the router's interfaces and adjacencies. Each link
    state advertisement is flooded throughout the routing domain. The
    collected link state advertisements of all routers and networks
    forms the protocol's topological database.

Hello protocol
    The part of the OSPF protocol used to establish and maintain
    neighbor relationships. On multi-access networks the Hello protocol
    can also dynamically discover neighboring routers.

Designated Router
    Each multi-access network that has at least two attached routers has

a Designated Router. The Designated Router generates a link state
advertisement for the multi-access network and has other special
responsibilities in the running of the protocol. The Designated
Router is elected by the Hello Protocol.

The Designated Router concept enables a reduction in the number of
adjacencies required on a multi-access network. This in turn
reduces the amount of routing protocol traffic and the size of the
topological database.

Lower-level protocols
    The underlying network access protocols that provide services to the
    Internet Protocol and in turn the OSPF protocol. Examples of these
    are the X.25 packet and frame levels for PDNs, and the ethernet data
    link layer for ethernets.

1.3 Brief history of SPF-based routing technology

OSPF is an SPF-based routing protocol. Such protocols are also referred
to in the literature as link-state or distributed-database protocols.
This section gives a brief description of the developments in SPF-based
technology that have influenced the OSPF protocol.

The first SPF-based routing protocol was developed for use in the
ARPANET packet switching network. This protocol is described in
[McQuillan]. It has formed the starting point for all other SPF-based
protocols. The homogeneous Arpanet environment, i.e., single-vendor
packet switches connected by synchronous serial lines, simplified the
design and implementation of the original protocol.

Modifications to this protocol were proposed in [Perlman]. These
modifications dealt with increasing the fault tolerance of the routing
protocol through, among other things, adding a checksum to the link

[Moy]   [Page 5]

RFC 1247   OSPF Version 2   . July 1991

state advertisements (thereby detecting database corruption). The paper
also included means for reducing the routing traffic overhead in an
SPF-based protocol. This was accomplished by introducing mechanisms
which enabled the interval between link state advertisements to be
increased by an order of magnitude.

An SPF-based algorithm has also been proposed for use as an ISO IS-IS
routing protocol. This protocol is described in [DEC]. The protocol
includes methods for data and routing traffic reduction when operating
over broadcast networks. This is accomplished by election of a
Designated Router for each broadcast network, which then originates a
link state advertisement for the network.

The OSPF subcommittee of the IETF has extended this work in developing
the OSPF protocol. The Designated Router concept has been greatly
enhanced to further reduce the amount of routing traffic required.
Multicast capabilities are utilized for additional routing bandwidth
reduction. An area routing scheme has been developed enabling